

Precipitation Enhancement

Precipitation enhancement is when clouds are artificially stimulated by “cloud seeding” to produce more rainfall/snowfall than they would naturally. Cloud seeding injects special substances into the clouds that enable snowflakes and raindrops to form more easily. Precipitation enhancement is the one form of weather modification conducted in California; hail suppression and fog dispersal (when fog is below freezing temperature) projects are conducted in other states.

Current Precipitation Enhancement in California

The first serious cloud seeding program in California began in 1948 on Bishop Creek in the Owens River basin for California Electric Power Company. Precipitation enhancement in the form of cloud seeding has been practiced continuously in several California river basins since the early 1950s. Most projects are located along the central and southern Sierra Nevada with some in the coast ranges. The projects use silver iodide as the active cloud seeding agent, supplemented by dry ice if aerial seeding is done. The silver iodide can be applied from ground generators or from airplanes. Occasionally other agents, such as liquid propane, have been used. In recent years, some projects have also been applying hygroscopic materials (substances which take up water from the air) as supplemental seeding agents. The following figure shows rain and snow enhancement programs for the 2002 - 2003 season.

Operators engaged in cloud seeding have found it beneficial to seed rain bands along the coast and orographic clouds over the mountains. The number of operating projects has tended to increase during droughts, up to 20 in 1991, but have leveled off to about 12 or 13 in recent years. The total area covered by these projects is around 13,000 square miles.



Policy statements by both the American Meteorological Society and the World Meteorological Organization support the effectiveness of winter orographic cloud seeding projects. The American Society of Civil Engineers has also shown interest with its Policy Statement No. 275 on Atmospheric Water Management in 2003 and a new report, ASCE/EWRI 42-04, “Standard Practice for the Design and Operation of Precipitation Enhancement Projects” in May 2004. This standards document will be a sequel to ASCE Manual No. 81, “Guidelines for Cloud Seeding to Augment Precipitation”, published in 1995.

Benefits from Precipitation Enhancement

In California, all precipitation enhancement projects are intended to increase water supply or hydroelectric power generation. The amounts of water produced are difficult to determine, but estimates range from a 2 to 15 percent increase in annual precipitation or runoff. A detailed study by the Utah Department of Natural Resources in 2000 showed an average increase in April 1 snowpack water content ranging from 7 to 20 percent from a group of projects which had been operating from 9 to 22 years. The overall estimated annual runoff increase was about 250,000 acre-feet, or 13 percent for the study area. Actual increases in annual runoff are probably significantly less in California than in Utah. One conservative estimate is that the combined California precipitation enhancement projects currently generate 300,000 to 400,000 acre-feet annually, which would be an average of about a 4 percent increase in runoff.

New NRC Report on Weather Modification

In the fall of 2003, the National Research Council released a report entitled “Critical Issues in Weather Modification Research”, which examined the status of the science underlying weather modification in the U. S. One conclusion widely reported by the press was that convincing scientific proof of the efficacy of weather modification was lacking and the authors proposed that a large sustained research program be developed to reduce the uncertainties of this technology. The report does not have much material on winter orographic cloud seeding, such as practiced in California and other western states, but does seem to concur that there is much evidence that it does work, possibly up to a 10 percent increase. Progress in seeding agent formulation and targeting was noted, although there is need for more research on these aspects as well.

Another 300,000 to 400,000 acre-feet per year may be available. Many of the best prospects are in the Sacramento River basin, in catchments that are not seeded now. The Lahontan regions are already well covered by cloud seeding projects, except for the Susan River. With the exception of the upper Trinity River watershed, and perhaps the Russian River, there is little new potential in the North Coast region because not much extra rainfall could be captured due to limited storage capacity. There is also potential to increase water production by more effective seeding operations in existing projects.

Precipitation enhancement should not be viewed as a remedy for drought. Cloud seeding opportunities are generally less in dry years. It works better in combination with surface or ground water storage to increase average supplies. In the very wet years, when sponsors already have enough water, cloud seeding operations are usually suspended.

Potential Costs

Costs for cloud seeding generally would be less than \$20 per acre-foot per year. State law says that water gained from cloud seeding is treated the same as natural supply in regard to water rights.

It is estimated that about \$3 million are being spent on current operations. Realizing the additional 300,000 to 400,000 acre-feet of potential new supply could require around \$7 million, which would be about \$19 per acre-foot. An initial investment of an estimated \$1.5 million to \$2 million in planning and environmental studies would also be required.

Major Issues for Precipitation Enhancement

There are major issues facing the use of precipitation enhancement practices.

Reliable Data

No complete and rigorous comprehensive study has been made of all California precipitation enhancement projects. Part of the reason is the difficulty in locating unaffected control basins for the standard target and nearby control area comparisons since wind variations would cause spillover into adjoining basins. Some studies of individual projects have been made in the past years on certain projects, such as the Kings River, which have shown increases in water.

Operational Precision

It is difficult to target seeding materials to the right place in the clouds at the right time. There is an incomplete understanding of how effective operators are in their targeting practices. Chemical tracer experiments have been provided support for current targeting practices.

Concern over Potential Impacts

Questions about potential unintended impacts from precipitation enhancement have been raised and addressed over the years. Common concerns relate to downwind effects (enhancing precipitation in one area at the expense of those downwind), long term toxic effects of silver, and added snow removal costs in mountain counties. The U.S. Bureau of Reclamation did extensive studies on these issues. The findings are reported in its Project Skywater programmatic environmental statement in 1977 and in its Sierra Cooperative Pilot Project EIS in 1981. The available evidence does not show that seeding clouds with silver iodide causes a decrease in downwind precipitation; in fact, at times some of the increase of the target area may extend up to 100 miles downwind (Ref. 1981 SCPP EIS). The potential for eventual toxic effects of silver has not been shown to be a problem. Silver and silver compounds have a rather low order of both acute and chronic toxicity. According to the Bureau of Reclamation, the small amounts used in cloud seeding do not compare to industry emissions of 100 times as much into the atmosphere in many parts of the country or individual exposure from tooth fillings. Watershed concentrations would be extremely low because only small amounts of seeding agent are used. Accumulations in the soil, vegetation and surface runoff have not been large enough to measure above natural background. A recent study (2004) done for Snowy Hydro Limited in Australia has confirmed the earlier findings cited above. In regard to snow removal, little direct relationship to increased costs was found for small incremental changes in storm size because the amount of equipment and manpower to maintain the roadway is essentially unchanged. For example, the effort is practically the same to clear 5.5 inches compared to 5 inches of snow on the road.

All operating projects have suspension criteria designed to stop cloud seeding any time there is flood threat. Moreover, the type of storms which produce large floods are naturally quite efficient in processing moisture into rain anyway. In such conditions, seeding is unlikely to make much difference.

Concern About Continuance of Hydroelectric Utility Seeding Operations

Four of the existing cloud seeding projects in California are sponsored by hydroelectric utilities. These four projects probably account for about 1/3 of the estimated statewide water production by cloud seeding. There is some concern that if these power plant facilities are sold, either as part of deregulation or for other reasons, potential new owners may not be interested in continuing cloud seeding. This would result in some loss in water supply for downstream users who have been indirectly benefiting from the added water. The State Public Utilities Commission is aware of this possibility and has tried to ensure, as a condition of transfer, that weather modification would continue.

Funding

Little federal research funding for weather modification has been available in the last 15 years. The Bureau of Reclamation had some funding in 2002 and 2003 in the Weather Damage Mitigation program. Desert Research Institute of Nevada did obtain a grant of \$ 318,000 from this source early in 2003 to evaluate its seeding in the eastern Sierra. The major portion of this research will be undertaken in the 2003-04 water year.

Recommendations to Increase Precipitation Enhancement

Following is a list of recommendations to increase precipitation enhancement:

1. Begin a new DWR program to investigate potential new cloud seeding projects. The State should support the continuation of current projects as well as the development of new projects and help in seeking research funds for both old and new projects.
2. DWR should collect base data and perform research on the effectiveness of California precipitation enhancement and how it could supplement other water supplies while minimizing negative impacts.
3. DWR should investigate the potential to augment Colorado River supply by cloud seeding, in cooperation with the Colorado River Board, the State of Arizona, the State of Nevada, and the U.S. Bureau of Reclamation.
4. DWR should keep abreast of current research on cloud physics and cloud modeling being done by the National Oceanic and Atmospheric Association (NOAA) labs and academic institutions. With improvement, these models may become tools to further verify and test the effectiveness of cloud seeding activities.
5. DWR should support efforts by California weather modification project sponsors, such as that proposed in 2002-03 by Santa Barbara County Water Agency, to obtain federal research funds for local research experiments built upon their operating cloud seeding projects.

Important Sources for Precipitation Enhancement

- ASCE Manual No. 81 “Guidelines for Cloud Seeding to Augment Precipitation” (1995)
- ASCE Policy Statement No. 275, “Atmospheric Water Resources Management, 2003
- ASCE/EWRI 42-04 “Standard Practice for the Design and Operation of Precipitation Enhancement Projects”, 2004.
- National Oceanic and Atmospheric Administration
- Desert Research Institute, Reno, Nevada
- American Meteorologic Society
- World Meteorological Organization
- USBR Project Skywater publications, various, 1975-1987, including those of
- the Sierra Cooperative Pilot Project in California.
- Sierra Cooperative Pilot Project, Environmental Assessment and Finding of
- no Significant Impact, USBR, Denver, 1981.
- NRC report “Critical Issues in Weather Modification Research”, The National Academies Press, Washington, DC, 2003.
- The Weather Modification Association’s Response to the NRC Report “Critical Issues in Weather Modification Research”, report of a review panel, Journal of Weather Modification, April, 2004.
- North American Interstate Weather Modification Council Response to NRC Report, April 2004, 2 pp, on www.naiwmc.org
- Snowy Hydro Limited, Cooma, NSW, Australia, “Assessment of the Environmental Toxicity of Silver Iodide and Indium Iodide, by Dr. Brian Williams, Adelaide University, 2004.